

X-X bond in X-X-N and further specification of either of the X's reduces the average intensity, then the description is not changed.

In addition to the work just mentioned, a generative model of rule formation has been pursued by Carl Farrell in his dissertation work directed by Professor Feigenbaum and Dr. Buchanan. He has written a program which accepts, as input, descriptions of specific molecules and all the primitive actions that might explain the mass spectra of those molecules. The output of the program is a set of general situation-action rules that describe classes of molecules that seem to be characteristically show evidence of significant actions.

PLANS

In the following period we plan to increase the performance capabilities of the theory formation program in several ways.

1. Sample Selection.

The program's current strategy is to find the rules exhibited by most or all of the molecules in the initial sample. If the molecules are diverse, the rules will be diverse. Thus, we plan to add a preprocessor that can select a "simple" set of molecules for the rule formation to work with. For example, unbranched (straight-chain) compounds should be expected to present fewer complications for initial theory formation than highly branched compounds. The effects of the complicating features can be studied after the simple rules have been found.

2. Rule Clarification.

After simple rules have been found, we want the program to clarify the conditions under which the rules hold. By studying more complicated molecules, the program can find the simple rules that no longer hold for these cases. For example, we want the program to discover that terminal alpha carbons (as in $\text{CH}_3\text{-X-N}$) are special. Or, the program should discover the effects of double bonds by examining new cases even though the molecules in the original set contained no double bonds.

3. Experimentation.

Because the original set of molecules contains the simpler examples from which it is easier to find characteristic mechanisms, the program will need to clarify rules in the way suggested under (2). For a human scientist, this means describing new experiments to perform that will help place limits on the range of applicability of the rules. Looking at additional arbitrary molecules may be helpful, but not as helpful as looking at the specific molecules that will resolve specific questions about the preliminary rule set.

4. Integration of Results.

When the program has examined two or more classes of molecules, it should be able to integrate the results into a common set of mechanisms (if any are common). The set of predicates used by the integration program may not have to be wider than the set used by the rule formation program, but one would expect the rules themselves to be more general. For example, integrating aliphatic amine and ether results should combine the separate alpha-cleavage rules (one with nitrogen, one

with oxygen) into a more general rule (specifying 'N or O', or 'heteroatom').

PART C REFERENCES (Published or submitted during this year)

D.H. Smith, B.G. Buchanan, W.C. White, E.A. Feigenbaum, C. Djerassi and J. Lederberg, "Applications of Artificial Intelligence for Chemical Inference X. INTSUM. A Data Interpretation Program as Applied to the Collected Mass Spectra of Estrogenic Steroids". Tetrahedron. In press.

B.G. Buchanan and N.S. Sridharan, "Analysis of Behavior of Chemical Molecules: Rule Formation on Non-Homogeneous Classes of Objects". In proceedings of the Third International Joint Conference on Artificial Intelligence, Stanford University (August, 1973). (Also Stanford Artificial Intelligence Project Memo No. 215.)

Related Publications

D. Michie and B.G. Buchanan, "Current Status of the Heuristic DENDRAL Program for Applying Artificial Intelligence to the Interpretation of Mass Spectra". August, 1973.

E.H. Shortliffe, S.G. Axline, B.G. Buchanan, T.C. Merrigan and S.N. Cohen, "An Artificial Intelligence Program to Advise Physicians Regarding Antimicrobial Therapy". Computers & Biomedical Research. In Press.

The undersigned agrees to accept responsibility for the scientific and technical conduct of the project and for provision of required progress reports if a grant is awarded as the result of this application.

10/12/73

Edward A. Feigenbaum

Date

Edward A. Feigenbaum
Principal Investigator

Edv

Feigenbaum

SECTION III

PART III - BUDGET DATA FOR
CURRENT BUDGET PERIOD

FROM

1/1/73

THROUGH

12/31/73

GRANT NUMBER

5 R24 RR00612-03

The following pertains to your CURRENT PHS budget. Do not include
it be used in determining the amount of support for the NEXT budget

sharing funds. This information in conjunction with that provided in Part I
period.

A. REVENUE CATEGORIES		CURRENT BUDGET (As approved by awarding agency) (1)	ACTUAL EXPENDITURES THRU 8/31/73 (Insert Date) (2)	ESTIMATED ADDITIONAL EXPENDITURES AND OBLIGATIONS FOR REMAINDER OF CURRENT BUDGET PERIOD (3)	TOTAL ESTIMATE EXPENDITURES AND OBLIGATIONS (Col. 2 plus Col. 3) (4)	ESTIMATED BALANCE (Col. 4 minus Col. 5) (5)
Personnel (Salaries)		111,885	12,722	37,483	110,205	1,680
Fringe Benefits		18,195	11,636	6,372	18,008	187
Consultant Costs		-	-	-	-	-
Equipment		8,000	2,945	1,704	4,649	3,351
Supplies		5,900	1,768	1,454	3,222	2,678
TRAVEL	Domestic	1,000	1,233	-	1,233	(233)
	Foreign	-	-	-	-	-
Patient Costs		-	-	-	-	-
Alterations and Renovations		-	-	-	-	-
Other		39,061	31,804	14,912	46,716	(7,655)
Total Direct Costs		184,041	122,108	61,925	184,033	8
Indirect Costs (if included in award)		76,958	47,579	26,882	74,461	2,497
TOTALS		\$260,999	\$169,687	\$88,807	\$258,494	2,505

Provide below to:

1. List all items of equipment purchased or expected to be purchased during this budget period which have a unit cost of \$500 or more.
Explain any significant balance or deficit shown in any category of Column 5.

D. List all other research support for Principal Investigator by source, project title, and annual amount.

SECTION III

SECTION III FISCAL DATA FOR
CURRENT BUDGET PERIOD
DAILY 12 MONTH Account A

FROM

1/1/73

THROUGH

12/31/73

GRANT NUMBER

5 R24 RR0612-03

The following pertains to your CURRENT PHS budget. Do not include cost sharing funds. This information in conjunction with that provided on Pg. will be used in determining the amount of support for the NEXT budget period.

A. BUDGET CATEGORIES		CURRENT BUDGET (As approved by awarding unit) (1)	ACTUAL EXPENDITURES THRU 8/31/73 (Insert Date) (2)	ESTIMATED ADDITIONAL EXPENDITURES AND OBLIGATIONS FOR REMAINDER OF CURRENT BUDGET PERIOD (3)	TOTAL ESTIMATED EXPENDITURES AND OBLIGATIONS (Col. 2 plus Col. 3) (4)	ESTIMATED UNOBLIGATED BALANCE (Col. 4 minus Col. 2) (5)
Personnel (Salaries)		38,931	24,147	13,248	37,395	1,536
Fringe Benefits		6,359	3,864	2,252	6,116	243
Consultant Costs		-0-	-0-	-0-	-0-	-0-
Equipment		-0-	-0-	-0-	-0-	-0-
Supplies		200	100	100	200	-0-
TRAVEL	Domestic	500	500	-	500	-0-
	Foreign	-0-	-0-	-0-	-0-	-0-
Patient Costs		-0-	-0-	-0-	-0-	-0-
Alterations and Renovations		-0-	-0-	-0-	-0-	-0-
Other		9,256	8,437	2,590	11,027	(1,771)
Total Direct Costs		55,246	37,048	18,190	55,238	8
Indirect Costs (If included in award)		22,673	14,038	7,567	21,605	1,068
TOTALS →		\$ 77,919	\$ 51,086	\$ 25,757	\$ 76,843	\$ 1,076

Use space below to:

- B. List all items of equipment purchased or expected to be purchased during this budget period which have a unit cost of \$1000 or more.
 C. Explain any significant balance or deficit shown in any category of Column 5.
 D. List all other research support for Principal Investigator by source, project title, and amount.

SECTION III

SECTION III FISCAL DATA FOR
CURRENT BUDGET PERIOD
(USUALLY 12 MONTHS) Account B

FROM

1/1/73

THROUGH

12/31/73

GRANT NUMBER

5 R24 RR-00612-03

The following pertains to your CURRENT PHS budget. Do not include cost sharing funds. This information in conjunction with that provided on Page 2 will be used in determining the amount of support for the NEXT budget period.

A. BUDGET CATEGORIES		CURRENT BUDGET (As approved by awarding unit) (1)	ACTUAL EXPENDITURES THRU 8/31/73 (Insert Date) (2)	ESTIMATED ADDITIONAL EXPENDITURES AND OBLIGATIONS FOR REMAINDER OF CURRENT BUDGET PERIOD (3)	TOTAL ESTIMATED EXPENDITURES AND OBLIGATIONS (Col 2 plus Col. 3) (4)	ESTIMATED UNOBLIGATED BALANCE (Subtract Col. 4 from Col. 2) (5)
Personnel (Salaries)		48,636	34,754	16,254	51,008	(2,372)
Fringe Benefits		7,864	5,561	2,763	8,324	(461)
Consultant Costs		-	-	-	-	-
Equipment Maint PDP-11 MAT-711		8,000	2,945	1,704	4,649	3,351
Supplies		5,500	1,548	1,274	2,822	2,678
TRAVEL	Domestic	-	98	-	98	(98)
	Foreign	-	-	-	-	-
Patient Costs		-	-	-	-	-
Alterations and Renovations		-	-	-	-	-
Other		10,000	4,066	9,033	13,099	(3,099)
Total Direct Costs		80,000	48,972	31,028	80,000	-
Indirect Costs (If included in award)		36,800	22,306	14,583	36,889	(89)
TOTALS →		\$116,800	\$ 71,278	\$ 45,611	\$116,889	\$ (89)

Use space below to:

- B. List all items of equipment purchased or expected to be purchased during this budget period which have a unit cost of \$1000 or more.
 C. Explain any significant balance or deficit shown in any category of Column 5.
 D. List all other research support for Principal Investigator by source, project title, and annual amount.

SECTION III

SECTION III FISCAL DATA FOR
CURRENT BUDGET PERIOD
(USUALLY 12 MONTHS) Account C

FROM

1/1/73

THROUGH

12/31/73

GRANT NUMBER

5-R24-RR00612-03

The following pertains to your CURRENT PHS budget. Do not include cost sharing funds. This information in conjunction with that provided on Page will be used in determining the amount of support for the NEXT budget period.

A. BUDGET CATEGORIES		CURRENT BUDGET (As approved by awarding unit) (1)	ACTUAL EXPENDITURES THRU 8/31/73 (Insert Date) (2)	ESTIMATED ADDITIONAL EXPENDITURES AND OBLIGATIONS FOR REMAINDER OF CURRENT BUDGET PERIOD (3)	TOTAL ESTIMATED EXPENDITURES AND OBLIGATIONS (Col. 2 plus Col. 3) (4)	ESTIMATED UNOBLIGATED BALANCE (Subtract Col. 4 from Col. 1) (5)
Personnel (Salaries)		24,318	13,821	7,981	21,802	2,516
Fringe Benefits		3,972	2,211	1,357	3,568	404
Consultant Costs		-	-	-	-	-
Equipment		-	-	-	-	-
Supplies		200	120	80	200	-
TRAVEL	Domestic	500	635	-	635	(135)
	Foreign	-	-	-	-	-
Patient Costs		-	-	-	-	-
Alterations and Renovations		-	-	-	-	-
Other		19,805	19,301	3,289	22,590	(2,785)
Total Direct Costs		48,795	36,088	12,707	48,795	-0-
Indirect Costs (If included in award)		17,485	11,235	4,732	15,967	1,518
TOTALS →		\$66,280	\$ 47,323	\$ 17,439	\$64,762	\$ 1,518

Use space below to:

- B. List all items of equipment purchased or expected to be purchased during this budget period which have a unit cost of \$1000 or more.
 C. Explain any significant balance or deficit shown in any category of Column 5.
 D. List all other research support for Principal Investigator by source, project title, and annual amount.

SECTION II--BUDGET (Continued)

Grant Number

5 R24 RR00612-03

B. Supplemental information regarding ITEMS in the proposed budget for the ~~same~~ period which require explanation or justification. (See instructions)

Salaries are lower on Account A because University guidelines for merit raises and cost of living raises were less than the budget estimates. Salary costs slightly exceed our previous estimate on Account B for two reasons. First, Mr. Reynolds (Electrical Engineer) left to take another job in June and Mr. Stefik (Computer Programmer) left to attend graduate school in September. Their replacements, Mr. Veizades and Mr. Tucker respectively, receive slightly higher salaries. Second, we had planned to contract with Varian Associates for maintenance of the MAT-711 Mass Spectrometer. Varian could not provide that support so we have taken on the task ourselves. Some of the added salary costs reflect associated machine shop and vacuum system support by local personnel. The budgeted salary amount on Account C is lower because of a three month lapse in support during the summer quarter of a student research assistant at full time. Also fall quarter support for a student research assistant will be less due to a change in personnel from a third year graduate student to a first year graduate student at a lower pay scale.

Fringe benefit costs on Account B are slightly higher reflecting the added salary costs. Also Stanford increased its fringe benefit rate from 16% to 17% in September.

Equipment maintenance costs on Account B are lower than expected for the MAT-711 spectrometer. This results from a lower price for locally provided maintenance, several months of instrument down time during the computing support transition, and better than average performance (no major breakdowns of expensive equipment).

Supplies are lower on Account B primarily because of instrument down time during the computing transition.

Travel expenses on Account B covers registration fees at a local Artificial Intelligence Conference.

"Other" expenses for Accounts A and C are higher than budgeted due to increased computing costs for two reasons. First, as the computer programs become more useful, we find the demand for computer time increases. Second, as a result of termination of ACME service, we could no longer take advantage of more favorable overnight rates than on the campus facility. Account B costs are also higher because of the termination of free ACME service and the resulting need to operate on the fee-for-service campus facility.

Indirect costs are less than expected on Accounts A and C because a larger portion of the grant was spent on campus computer facilities which is not subject to indirect costs. Account B indirect costs are slightly higher because of an increase in the University indirect rate from 46% to 47% of Net Total Direct Costs on September 1, 1973.

SECTION II

SECTION II—BUDGET (USUALLY 12 MONTHS)

FROM

1/1/74

THROUGH

4/30/74

GRANT NUMBER

5 R24 RR00612-04

A. ITEMIZE DIRECT COSTS REQUESTED FOR NEXT BUDGET PERIOD

PERSONNEL		TIME OR EFFORT %/HRS. (c)	SALARY REQUESTED (d)	FRINGE BENEFITS (See Instructions) (e)	TOTAL (f)	
NAME (Last, First, Initial) (a)	TITLE OF POSITION (b)					
	PRINCIPAL INVESTIGATOR					
See separate detailed listing						
Subtotals			\$ 35,802	\$ 6,087		
(Indicate cost of each item listed below)					TOTAL (Columns (d) and (e))	\$ 41,889
CONSULTANT COSTS (See Instructions)						\$ -0-
EQUIPMENT						\$ -0-
SUPPLIES See Accounts A, B & C						\$ -0-
						\$ 1,683
TRAVEL	DOMESTIC					400
	FOREIGN					-0-
PATIENT COSTS (See Instructions)						-0-
ALTERATIONS AND RENOVATIONS						-0-
OTHER EXPENSES (Itemize)						-0-
See Accounts A, B & C						\$ 17,440
TOTAL DIRECT COST (Enter on Page 1, Item 10)						\$ 61,412

INDIRECT
COST

(See Instructions)

47 % S&W*
% NTDC

*If this is a special rate (e.g. off-site), explain.

Date of DHEW Agreement:

Pending

☐ Not Requested☐ Under negotiation with

SECTION II

SECTION II—BUDGET (USUALLY 12 MONTHS)

FROM

1/1/74

THROUGH

4/30/74

GRANT NUMBER

5 R24 RR00612-04

A. ITEMIZE DIRECT COSTS REQUESTED FOR NEXT BUDGET PERIOD

ACCOUNT B

PERSONNEL		TIME OR EFFORT %/HRS. (c)	SALARY REQUESTED (d)	FRINGE BENEFITS (See Instructions) (e)	TOTAL (f)
NAME (Last, First, Initial) (a)	TITLE OF POSITION (b)				
	PRINCIPAL INVESTIGATOR				
See separate detailed listing					
Subtotals			\$ 14,886	\$ 2,531	
(Indicate cost of each item listed below)					
TOTAL (Columns (d) and (e))					\$ 17,417
CONSULTANT COSTS (See Instructions)					\$ -0-
EQUIPMENT					\$ -0-
SUPPLIES Electronic supplies - \$333; Gas chromatograph supplies (columns, gases, etc.) - \$250; Organic chemicals, glassware, etc. - \$500; Data recording paper (uv sensitive, calcomp, brush) - \$333; Mini-computer supplies (paper, ribbons, etc.) - \$167					\$ 1,583
TRAVEL	DOMESTIC				\$ -0-
	FOREIGN				\$ -0-
PATIENT COSTS (See instructions)					\$ -0-
ALTERATIONS AND RENOVATIONS					\$ -0-
OTHER EXPENSES (Itemize)					
Telephone, reproduction, office supplies, etc. - \$500					
Computer terminal rental - \$533					
Mini-computer maintenance contract - \$1,000					
Mass spectrometer repair and replacement parts - \$1,667					
Computer usage (370/158) - \$4,300					\$ 8,000
TOTAL DIRECT COST (Enter on Page 1, Item 10)					\$ 27,000

INDIRECT
COST

(See Instructions)

% S&W*

47 % TDC NTDC

*If this is a special rate (e.g. off-site), explain.

Date of DHEW Agreement:

Pending

☐ Not Requested☐ Under negotiation with

SECTION II

SECTION II—BUDGET (USUALLY 12 MONTHS)

FROM
1/1/74THROUGH
4/30/74GRANT NUMBER
5 R24 RR00612-04

A. ITEMIZE DIRECT COSTS REQUESTED FOR NEXT BUDGET PERIOD

ACCOUNT A

PERSONNEL		TIME OR EFFORT %/HRS. (c)	SALARY REQUESTED (d)	FRINGE BENEFITS (See Instructions) (e)	TOTAL (f)
NAME (Last, First, Initial) (a)	TITLE OF POSITION (b)				
	PRINCIPAL INVESTIGATOR				
See separate detailed	listing				
		Subtotals	\$ 12,930	\$ 2,198	
(Indicate cost of each item listed below)					
TOTAL (Columns (d) and (e))					\$ 15,128
CONSULTANT COSTS (See Instructions)					\$ -0-
EQUIPMENT					\$ -0-
					\$ -0-
SUPPLIES - Office					\$ 50
					\$ 200
					\$ -0-
TRAVEL					\$ -0-
DOMESTIC					\$ -0-
FOREIGN					\$ -0-
PATIENT COSTS (See Instructions)					\$ -0-
ALTERATIONS AND RENOVATIONS					\$ -0-
OTHER EXPENSES (Itemize)					\$ -0-
Publications - \$100					
Computer Terminal Rental - \$500					
Computing Time & Storage - \$3240					\$ 3,840
TOTAL DIRECT COST (Enter on Page 1, Item 10)					\$ 19,218

INDIRECT
COST
(See Instructions)% S&W*
47 % TDC-NTDC

*If this is a special rate (e.g. off-site), explain.

Date of DHEW Agreement:
Pending☐ Not Requested
☐ Under negotiation - to

SECTION II

SECTION II—BUDGET (USUALLY 12 MONTHS)		FROM 1/1/74	THROUGH 4/30/74	GRANT NUMBER 5 R24 RR00612-04	
A ITEMIZE DIRECT COSTS REQUESTED FOR NEXT BUDGET PERIOD				ACCOUNT C	
PERSONNEL		TIME OR EFFORT %/HRS. (c)	SALARY REQUESTED (d)	FRINGE BENEFITS (See Instructions) (e)	TOTAL
NAME (Last, First, Initial) (a)	TITLE OF POSITION (b)				
	PRINCIPAL INVESTIGATOR				
See separate detailed listing					
Subtotals			\$ 7,986	\$ 1,358	
(Indicate cost of each item listed below) TOTAL (Columns (d) and (e))					\$ 9,344
CONSULTANT COSTS (See Instructions)					\$ -0-
EQUIPMENT					\$ -0-
SUPPLIES Office					\$ 50
TRAVEL	DOMESTIC				\$ 200
	FOREIGN				\$ -0-
PATIENT COSTS (See Instructions)					\$ -0-
ALTERATIONS AND RENOVATIONS					\$ -0-
OTHER EXPENSES (Itemize)					\$ -0-
Publications - \$100					
Computer Terminal Rental - \$500					
Computer Time & Storage - \$5,000					
					\$ 5,600
TOTAL DIRECT COST (Enter on Page 1, Item 10)					\$ 15,194
INDIRECT COST (See Instructions)		_____% S&W* 47 % FDC-NTDC *If this is a special rate (e.g. off-site), explain.		Date of DHEW Agreement: Pending	
				<input type="checkbox"/> Not Requested <input type="checkbox"/> Under negot.	

SECTION II—BUDGET (Continued)	Grant Number 5 R24 RR00612-04
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B. Supplemental information regarding ITEMS in the proposed budget for the next period which require explanation or justification. (See instructions)

All of the proposed budget figures are based on previous and current operating expense experience within the \$61,417 total awarded. Manpower, supplies and other costs have been minimized to provide as much as possible for computing costs on the new SCIP 370/158 computer facility for Account B. Even so, the money which can be allocated to computing is below expected operating costs. This will limit the number of samples which can be processed through our mass spectrometry instrumentation.

We anticipate the possible requirement to pay 50% of a \$10,000 U.S. Customs duty on Account B for the purchase of the MAT-711 Spectrometer from Varian-MAT in Germany. The other 50% would be paid by Varian. This was previously budgeted in year 02 but was deferred by NIH. We have been negotiating with the Department of Commerce for a waiver of these fees based on the unavailability of a similar instrument domestically. These negotiations are still underway with uncertain outcome. We do not include the \$5,000 in this budget but will negotiate separately with BRB for reinstatement of the deferred funds if payment is necessary.

Personnel costs for Accounts A and C are supporting the same people with the exception of the student research assistant on Account C. Mr. Farrell, who previously worked on the project left and has been replaced by Mr. Mark Stefik who, as a first year graduate student, receives slightly less salary. Drs. Buchanan, Brown, Carhart and Dromey, who currently work for the project but receive support elsewhere, are shown at zero salary level to indicate a realistic manpower level with regard to computing and other related expenses. The requested manpower on Account B is required for the operation and maintenance of the mass spectrometry systems. Again, the same personnel receive support with two exceptions. Mr. Veizades, who replaced Mr. Reynolds, provides electronic and mechanical engineering support for system development and maintenance, and Mr. Tucker, who replaced Mr. Stefik, provides computer programming support for data system development and maintenance.

Travel estimates are a bit higher on Accounts A & C in light of the deficit experienced in the current year and the expected continuation of travel needs.

No money is requested for equipment purchase.

Supplies and "other" budget items are detailed in each category and should be self-explanatory. All costs are estimated based on past experience and have been held to the lowest minimum due to the total budget level allotted for the year 04. Actual computer service will be somewhat less than anticipated, however, because of the termination of ACME service. Equipment maintenance costs for the PDP-11/20 minicomputer and the MAT-711 spectrometer have been budgeted under "other". Note that we have taken on, as the most cost effective approach, the maintenance of the spectrometer in addition to other locally built equipment. We had previously planned to obtain this service from Varian-MAT, but this proved unsatisfactory.

SUPPORTING DATA FOR ADMINISTRATIVE EXTENSION

We have discussed with the Biotechnology Resources Branch possible relationships between a continuation proposal of this DENDRAL Resource-Related Research grant and the proposed SUMEX nationally shared computing resource (RR-00785). The problem of synchronizing these proposals may entail a request for administrative extension of the present DENDRAL award to prevent lapse of constituent programs pending their review in different organizational formats.

The monthly costs of such an extension are detailed here, on the basis of austere minima for the continuity of the team's work. Our attached estimate for the "next" period (1/1/74-4/30/74) already represents such a baseline budget since we have had to absorb significantly increased computing costs (see "current" and "next" budget explanations) in reducing manpower support. The numbers shown below are therefore the monthly direct costs derived straightforwardly from the budget estimate for the next period. They would be allocated among the various budget categories in a similar manner.

Part A:	\$4,805 monthly
Part B:	\$6,750 monthly
Part C:	<u>\$3,798 monthly</u>
Total:	\$15,353 monthly (direct costs)